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ABSTRACT

Previous research of classroom teaching and learning revealed that students have critical misconceptions about how plants get their food and that these misconceptions remain unchanged despite instruction using activities in the Science Curriculum Improvement Study (SCIIS) unit on producers. Because the experimental sequence described in SCIIS is not enough to help students relinquish their misconceptions about food for plants, a text was developed to clearly address students' misconceptions and to make explicit the contrast between their misconceptions and the scientific explanations of photosynthesis. This document is the teacher's guide version of the student text. In addition to student material, it contains an overview of students' common misconceptions about food for plants as well how to use text chapters in conjunction with the SCIIS unit on producers. (JN)

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Research Series No. 133

FOOD FOR PLANTS: TEACHER'S GUIDE

Kathleen Roth

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FOOD FOR PLANTS: TEACHER'S GUIDE

Kathleen Roth

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Abstract

This is a teacher's guide version of a student text that was used in the research project Science Textbooks and Student Learning. An earlier IRT study of classroom science teaching and student learning had revealed that students held critical misconceptions about how plants get their food. These misconceptions remained unchanged despite instruction using Science Curriculum Improvement Study (SCIIS) activities. This text was written to be used in conjunction with those SCIIS activities. The text was developed to help teachers recognize student misconceptions and to help students give up their misconceptions in favor of the scientific explanation of photosynthesis. In the first phase of the project, the text was used by one teacher in her three fifth-grade classes. A second phase of the study explored middle-school students' reading of the text in isolation of any instruction and compared this experimental text with two traditional texts (forthcoming).

FOOD FOR PLANTS TEACHER'S GUIDE

Kathleen Roth[1,2]

This text was developed as a result of work on the Elementary Science Project at the IRT. (See Eaton, Anderson, & Smith, 1984; Smith, 1984; and Smith & Anderson, 1984.) Over the last two years, project personnel have observed fifth-grade science classes and given pre- and posttests to the students in these classrooms.

The study has convinced project staff that most fifth-grade students hold certain fundamental misconceptions about how plants get their food. As a result, instruction must clearly point out to students the contrast between their own misconceptions and more appropriate scientific conceptions. For example, students not only have to learn the scientific explanation of how plants get food, they must also give up their faulty notions about plants and their food.

This text was written to accompany the experimental sequence described in the SCIIS (Science Curriculum Improvement Study, second edition) unit called Producers (Chapters 4, 5, and 6) (Knott, Lawson, Karplus, Their, & Montgomery, 1978). Because the experimental sequence described in SCIIS is not enough to help students relinquish their misconceptions about food for plants, this text was developed for two purposes:

1. To help teachers elicit, recognize, and address student misconceptions.

2. To help students develop a better understanding of the goal conceptions of the unit by

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[1]Kathleen Roth is a research assistant with the IRT's Science Teaching Project and a doctoral candidate in science education in MSU's Department of Teacher Education.

[2]The author wishes to acknowledge the assistance of Saundra Dunn, who illustrated the text.

--eliciting students' own ideas about how plants get their food,

--helping students recognize that some of their own ideas cannot explain the experimental results,

--providing an explanation of photosynthesis that directly addresses students' misconceptions,

--helping students who have misconceptions see the conflict between their own ideas and the notion of photosynthesis, and

--providing many opportunities for students to practice applying the idea of photosynthesis to new situations.

The text has been used in classrooms with great success (Roth, 1984).

How to Use This Teacher's Guide

The text was written to clearly address students' misconceptions and to make explicit the contrast between students' misconceptions and scientific explanations of photosynthesis.

Questions are an important part of this text. The questions serve two important purposes, exploration and application.

Exploration

Some questions are placed in the text to elicit information from students about their misconceptions. Common student answers to these questions are given in this teacher's guide to help the teacher recognize particular misconceptions students hold. Thus these questions are diagnostic tools that can help the teacher guide instruction appropriately. The teacher's guide presents common student answers to these questions and contrasts them with scientifically appropriate answers.

Application

Some questions give students a chance to practice and apply new concepts. These questions provide opportunities for students to synthesize and think through what they have learned. It is important that these questions also

serve a diagnostic purpose, pinpointing the persistence of misconceptions and the failures to replace the misconceptions with scientific explanations. The teacher's guide provides notes to the teacher about which concepts students should be expected to apply in answering these questions.

Notes to the teacher about common student answers and desired answers to questions appear in italic type on the pages facing the corresponding student page. The teacher can thus see the student page and information about expected answers at the same time.

An overview of students' common misconceptions about food for plants is presented at the end of this teacher's guide.

When to Use the Text Chapters

Chapter One is intended as an introduction to the unit and can be used before Chapter 4 in the SCIIS sequence. Chapter Two is to be used after the completion of Chapter 4 in the SCIIS sequence, "Which bean parts grow?" Chapter Three is to be used after the completion of the experiment with grass plants described in Chapter 5 of the SCIIS sequence, "Do plants need light to grow?" Chapter Four can be used after or in place of Chapter 6 in the SCIIS sequence, "Cotyledons."

Common Student Answers

This question is designed to elicit and explore students' conceptions of food. Students are likely to define food as anything you eat. Some may contrast food with liquids (food is what you chew, not what you drink). Some students may say that food is something that helps you live and grow.

Although it is true that food is something that helps you live and grow, students using this definition of food tend to consider anything that helps you live and grow as food. Many students, for instance, consider water and vitamins as food.

Scientific Definition of Food

In contrast to students' definitions of food, scientists define food in terms of a specific function: It provides the energy that living things need to live and grow. By this definition, water is not food because it does not provide energy. Water is needed for life, but it is not a food. Both juice and sugar are food because they provide energy.

Students should not be expected to understand the scientific conception of food at this point. The concept is presented to them on page 1. The definition is presented here to help students begin to question their beliefs that water and fertilizer are food for plants. Students will be asked to refer back to this definition again later in the unit.

FOOD FOR PLANTS

Chapter One - Introduction

In some ways, food for plants is like food for humans. But in other very important ways, food for plants is quite different from food for humans. In this chapter we will investigate how plants get their food.

What is food?

In order to understand how plants get their food, you need to understand the scientific meaning of the word "food." This definition may be very different from what you usually think of as food.

Write down how you would define food. _____

_____

_____

_____

In your definition, is juice a food? _____

Is water a food? _____

Is sugar a food? _____

In everyday life, people have lots of ways of thinking about what food is. Some would say juice is not a food, because you do not chew it. Others would say that all three of these are foods because they are all taken into our bodies.

But scientists all agree on one special definition of food. When we think about food in this chapter, we will always use the scientists' definition of food.

Scientists define food as anything that gives living things the energy they need to grow and to keep all their inside parts working properly. The most important word in this definition is energy. Energy is the ability to do work. Energy is not something you can see, but it is something that every living thing must have in order to live. Living things get their energy from food. Food must supply energy. The energy in plants' and animals' food enables them to do work: to grow, to reproduce, to move, and so on.

Because juice and sugar supply energy to living things, scientists would consider them both food. Scientists would not consider water a food, because it does not give living things any energy. Vitamin pills also are not food by this definition. They do not supply energy. Using the scientific definition of food, explain why you could not live on water and vitamin pills alone.

How Food for Plants is Like Food for Humans

Both humans and plants need food for the same reason. They need food because food gives them the energy that they must have to grow and to keep all their parts working properly. Cars use gasoline for energy to make all the parts inside the engine work properly. Living things get all their energy from food. Both plants and humans must have this energy-supplying substance.

How Food For Plants is Different From Food for Humans

Plants cannot get food the way we do. They do not have mouths, and they cannot go out and buy food from the store! So how do they get food? What kind of food do they use?

Both of the questions on this page are exploratory questions designed to elicit students' misconceptions about food for plants. Do not expect students to have the scientific conception of food for plants at this point. The question will help make both you and the students aware of their incoming conceptions.

Common Student Answers

Plants get food by taking it in from the soil.
Plants get food from fertilizer in the soil.
Plants get food from the sun, water, air, soil, fertilizer.
Food for plants is the sun, water, air, fertilizer, shelter, etc.
Plants' food is fertilizer.

Some students tend to think about anything the plant <u>needs</u> as food for the plant. Others think that whatever plants take into their bodies ("eat") is food for plants. Still others identify fertilizer alone as food for plants.

Scientific Conception

While many students consider raw materials in the plants' environment as the plants' food, the scientific conception is that plants get food by making it themselves by using energy from the sun to change water and air (carbon dioxide) into food. This process, called photosynthesis, takes place inside the plants' leaves. This is the goal concept of the unit. By the end of the unit, students should relinquish their misconceptions in favor of this scientific conception.

Write down your ideas about how plants get food. _____

_____

_____

_____

_____

Write down your ideas about what kind of food plants use.

_____

_____

_____

_____

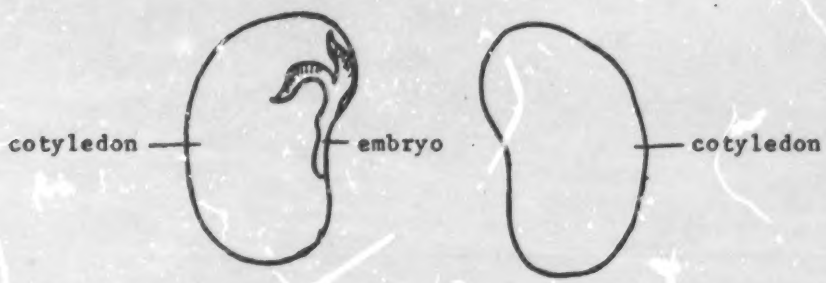
In this unit, we will find out what food is for plants and how plants get their food. As we go along, compare what you find out with what you have just written. See if your ideas change in some ways.

Chapter Two - Do Seeds Provide Food For Plants?

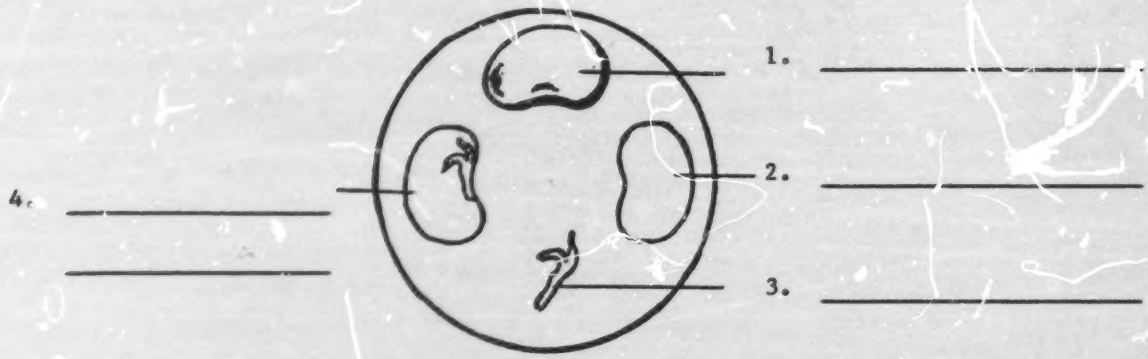
One way to get information about plants' food is by doing experiments with plants. Read the following description of the experiment you did with seeds. As you read this description, think about what clues this experiment gives about food for plants.

Experiment: Do seeds provide food for plants?

When you split the bean seed in half, you saw that a bean seed has three parts. There was a little part that looks like a miniature plant. It is called an embryo and will grow into the adult plant. The two large oval parts of the seed are the cotyledons:



In your experiment, different parts of the seeds were placed on moist paper towels in a dish and kept in a warm place. They looked like this at the beginning of the experiment:



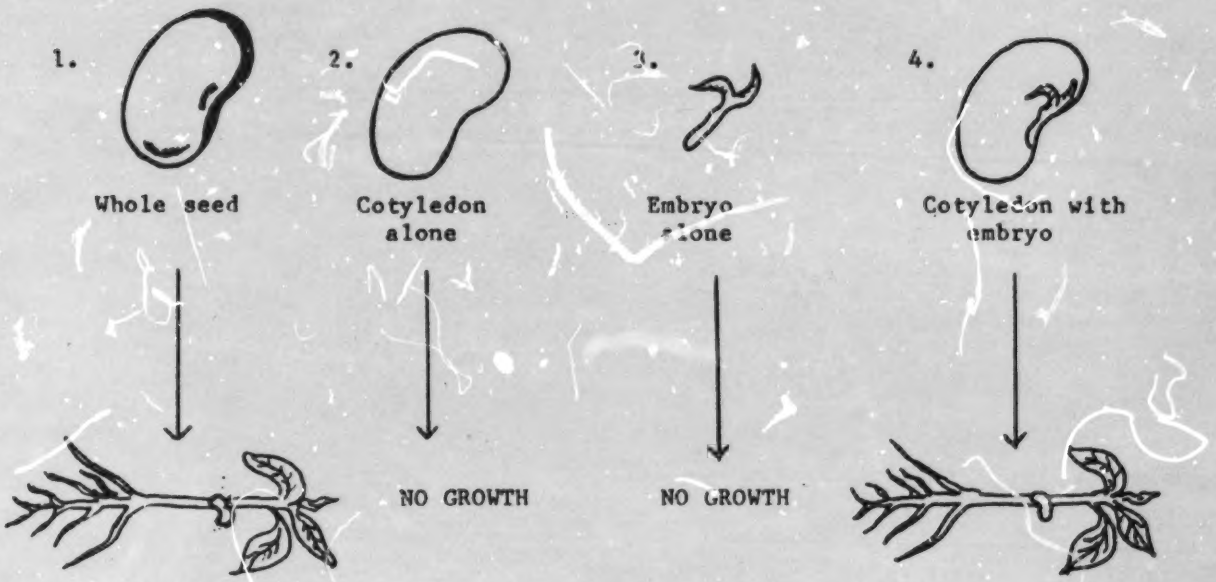
Label the picture. Number 1 shows the whole bean seed. Number 2 is one cotyledon half. It has no embryo attached to it. Number 3 is an embryo. It is not attached to a cotyledon. Number 4 is an embryo attached to one cotyledon half.

Constructing Scientific Explanations

Our research has shown that students have a difficult time constructing scientific explanations of experimental observations. Their explanations tend to focus only on observable effects (what happened) rather than on reasons or functions.

Explanations 1 and 3 are ones students typically give. Students tend not to think about unseen processes occurring within the plant. This section is designed to give students information about how to make a good explanation of their observations and to stimulate students to think about what is happening inside the bean seed.

After about two weeks, some of the seed parts had grown and others had not. Here is what happened to each of the four parts:



How can we explain these observations? A good explanation for a science experiment does not just tell what you saw. A good explanation gives a reason to explain <u>why</u> something happened. Sometimes you have to think about things you cannot see to come up with a good explanation of what you <u>do</u> see.

Your observations of the bean seeds can be used as one kind of evidence about how plants get their food. Below are three possible explanations of what you saw in the experiment. Decide which one you think is the <u>best</u> explanation of the results:

___ 1. The seeds with an embryo attached to a cotyledon grew. The embryo alone did not grow. The cotyledon alone did not grow.

___ 2. The embryo will grow when attached to a cotyledon, because the cotyledon provides the embryo with food.

___ 3. The embryo will grow when attached to a cotyledon, because it needs the cotyledon.

Here are the explanations again. Which one did you choose?

☐ 1. The seeds with an embryo attached to a cotyledon grew. The embryo alone did not grow. The cotyledon alone did not grow.

☐ 2. The embryo will grow when attached to a cotyledon, because the cotyledon provides the embryo with food.

☐ 3. The embryo will grow when attached to a cotyledon, because it needs the cotyledon.

Number 1 is not a good explanation of the results. It just tells you what you saw happen in the experiment. It does not tell why this happened. It does not give any reasons. It does not tell what might be happening inside the plant that could explain why the embryo only grew when attached to the cotyledon.

Number 3 gives a reason. It says that the embryo grows only when attached to the cotyledon, because it needs the cotyledon. But this explanation does not tell why the embryo needs the cotyledon. It is not a very complete explanation.

Number 2 is the most complete explanation. It gives a reason why the embryo grows when attached to a cotyledon. We cannot see the embryo getting food from the cotyledon, but we can see that it grows only when attached to a cotyledon. A logical explanation for this is that the cotyledon is giving food to the embryo.

So Numbers 1 and 3 are not as complete explanations as Number 2. They only describe what we can see. They do not talk about what might be happening inside the seed that could explain why the seed grew only when it had a cotyledon. Scientists try to explain their observations of plants by thinking about what is going on inside the plant.

Thus we can explain our experiment with the idea that plants get food from the cotyledon. But this is only part of the story. Where does the food in the cotyledon come from? That is a question we will come back to later. First, let's explore other possible sources of food for plants.

This exploration question is designed to stimulate students to look for a functional explanation of the grass seed experiment. *(See page T-7.)*

Common Student Answers

Because plants need light to live.
They can start to grow in the dark, but they need light to continue to grow.

Students typically give explanations that focus only on what they saw. This explanation is true but does not reveal any thinking about the function the light serves for the plant. Remind students about the characteristics of a scientific explanation to help them think about the functions of light in plants.

Scientific Conception

Students should not be expected to develop the following scientific explanation based only on the experimental results. However, subsequent instruction will help students develop a functional explanation that connects this experiment with food:

Plants have to have food for energy to live and grow. Plants can begin to grow in the dark because they get food from the cotyledon. When the cotyledon is all used up, the plant in the dark dies but the plant in the light lives. Therefore, the light must somehow provide the plants with food. The "somehow" will be explained in this chapter.

Chapter Three - An Experiment with Grass Plants

Let's look at another experiment and see what we can find out about food for plants. In this experiment you planted grass seeds in some soil, gave them water, and put them in the dark. The plants grew quite tall in the dark, but they also began to look very unhealthy. The grass plants that were moved to the light got green and healthy looking and continued to grow. But the plants left in the dark <u>died</u>. Explain why you think the grass began to grow in the light and the dark, but then died in the dark. _____

_____

_____

_____

_____

Do soil and water provide food for plants?

Soil is not food. But it does contain things in it such as minerals, water, insects, etc. Are these food for plants? Do plants take in food from the soil through their roots?

In your experiment the grass plants in the light and the grass plants in the dark had the same soil and the same amount of water. Both had soil and water, but the plants in the light lived and the plants in the dark died.

The reason the plants in the dark died is that they did not have food to supply the energy they needed to continue living and growing. The soil and water were not enough. They did not supply the energy needed for life and growth. The plants had water and soil, but they had no food. Plants cannot get their food from soil or water, so the plants in the dark died from lack of food.

Does sunlight provide food for plants?

Your experiment demonstrated that plants need light to continue living and growing. Does this mean that sunlight is food for plants?

In order to find out if sunlight is food for plants, you need to know more about plants than we can observe in this experiment. A good explanation of why the plants in the light live and why the plants in the dark die must tell us more than what happened. It must tell us more than "plants need light." We want to know why the plants need the sun.

Scientists have developed good explanations for these observations. They have conducted many experiments and done lots of thinking about what is going on inside the plants. What happens to the sunlight when it enters the leaves of plants? Scientists have found that the sun is not "eaten" or digested by the plant. It is not food for plants.

But sunlight does have something to do with food for plants. Scientists have found that plants are able to do something with the sun that no humans or animals are able to do. Neither worms, fish, birds, monkeys, nor people can do what plants can do with the sun.

Plants can use the sunlight to make their own food in their leaves. Read the next section to find out how plants make food inside their leaves. While you read the paragraph, write each underlined word in the correct place on Diagram #1.

You might have students take turns explaining this process to the class, talking about different plants in their environment (How does this fern in our classroom get food? the grass outside? the plants in an aquarium? etc.). This will give students important practice in putting together the scientific explanation of how plants get food. Hearing it repeated gives students additional time to put all the pieces together.

How Plants Use the Sun To Make Their Own Food

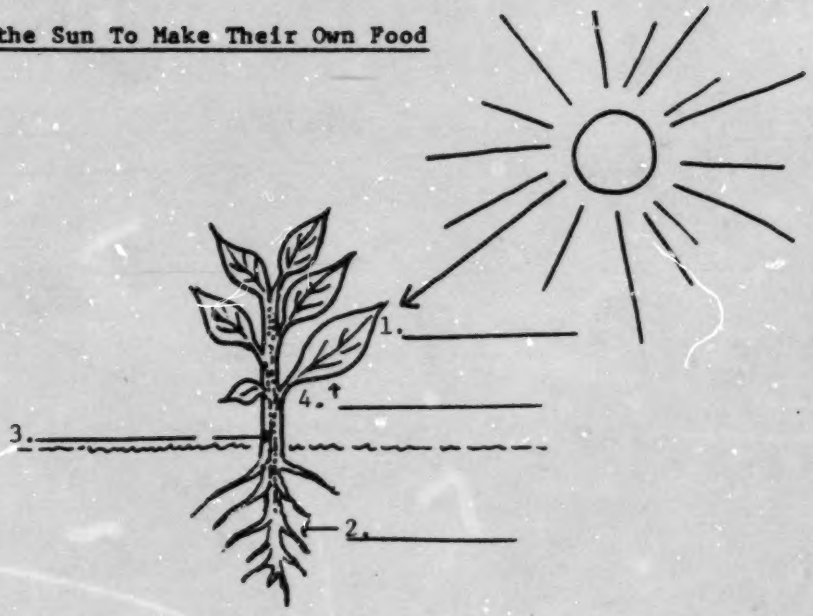


Diagram #1

The sunlight is absorbed into the leaves. A green pigment in the leaves, called chlorophyll, is able to trap the sun's energy in the leaf. Plants take in water from the soil. The water travels from the roots up tubes inside the plant. Eventually the water reaches the leaves. Air enters the leaves through tiny holes in the leaves. When all three of these ingredients (sun, water, air) are in the leaf, the plant can make food. It uses energy from the sun to mix water and air together and make a totally new substance out of them - food! This food is not water. It is not air. It is not just a mixture of water and air. It is a new substance.

This food-making process is called photosynthesis. "Photo" means light, and "synthesis" means putting together. Photosynthesis is using light to put together air and water to make food. The energy from the sun is used to split apart the water and air molecules. Then the pieces of the molecules are rearranged to make a totally new substance.

Accurate: *The cartoon shows that food made by the parent plant is stored in the cotyledons of seeds. This provides a food source for the new plant. When that food source is used up, the plant must make its own food using sunlight as an energy source.*

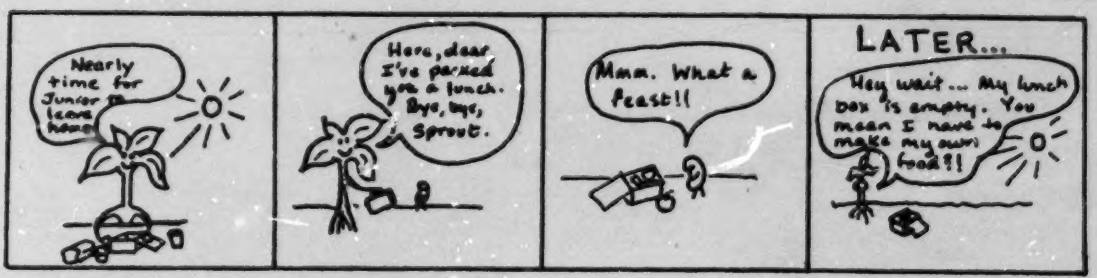
Inaccurate: *Students may note that the food for the young plant is "packed" in the cotyledon, not in a lunch box and that plants don't have hands or feet.*

It is also very important to talk about how plants make food; students may think that plants make food like humans make a lunch. This cartoon shows a plant making a lunch just like people do. In contrast, photosynthesis is a chemical process that occurs inside plants' leaves by which non-food substances (air and water) are chemically changed into food. When plants make food, they are creating food. When people "make lunches" they are just taking food and rearranging it. They are not creating food. When we talk about plants making food, we mean something very different from when we say that people make lunches.

Only plants are able to use sunlight to make their own food inside their bodies. Imagine if people could make food in this way. All we would have to do when we were hungry is to get plenty of air and water and to stand in the sun. No more trips to the grocery store or McDonald's!

Plants do not get food from the soil, or the water, or the grocery store. They get all the food they need by making it themselves.

But you may remember another source of food for plants we talked about earlier. We said young plants (embryos) get food from their cotyledons. Isn't that a different source of food for plants? No, not really. The food in the cotyledon was not taken in from the soil, the water, or the air. The food in the cotyledon was <u>made</u> by the parent plant by combining sun, water, and air. The parent plant can make more food than it needs. Some of the extra food is stored in the cotyledons of each seed. In this way when the seeds fall off the parent plant, they will have a ready source of food for the new embryo.


Nearly time for Junior to leave home.
Here, dear I've packed you a lunch. Bye, bye, Sprout.
Mmm. What a feast!!
LATER...
Hey, wait... My lunch box is empty. You mean I have to make my own food?!

In what ways is this cartoon accurate? inaccurate? _____

_____

_____

_____

_____

_____

The questions on this page are application questions. Students are expected to use new knowledge they have gained to develop scientifically appropriate answers. Unlike exploration questions, these questions do have right and wrong answers.

Why the Seed Needs the Cotyledon

The key concept that students should apply in answering this question is that plants can only make their own food in the light. They cannot make food in the dark. A plants' only source of food in the dark is the food stored in the cotyledon.

Be on the lookout for any student answers that suggest that the plant can get food from any sources other than the cotyledon or by making it themselves--such as water, fertilizer, sunlight, or soil.

Is "Plant Food" Food for Plants?

The key concept that students should apply in answering this question is the scientific definition of food: Food is anything that gives living things the energy they need for growth and for maintaining life processes. Since plant food does not give plants energy, it is not food.

Explain why the seed needs food in the cotyledon to start growing. (Why can't the seed just make its own food?) _____

_____

_____

_____

Does "plant food" from the store provide food for plants?

"Plant food" or fertilizer that you buy in the store contains minerals that help the plants grow better, but it does not supply plants with any energy. Think back about our definition of food (look on p. 2). Is "plant food" really food by the scientists' definition? Explain. _____

_____

_____

_____

_____

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The questions on this page are application questions. The key concepts that students should apply are noted on this page.

1. *The key concept that students should use in answering this question is that the cotyledons provide food for the young grass plants. The young grass plant has no other source of food until it reaches sunlight and can make its own food.*

   Although student answers may correctly describe the cotyledon providing food for the growing grass seed, students may continue to think that the growing plant can get food from other sources too. You may want to explore this during discussion of this question.

2. *This question also asks students to apply their knowledge about the function of the cotyledon: All grass seeds have food in the cotyledon. They can use this food to begin growing whether they are in the light or in the dark.*

   Students may say that the plants grew because they had food, but they may still not specify the source of that early food and may be thinking about a variety of sources of food (soil, fertilizer, etc.). They may also fail to give an explanation that goes beyond the observational level (for example, "The plants grew because plants can begin to grow in the dark."). Push students to give explanations about <u>why</u> the plants could grow in the dark. Ask students who are having difficulty if plants in the dark have any source of food.

3. *There are two main concepts students need to use to answer this question: (1) that plants cannot make their food in the dark and will die without food and (2) that plants cannot get food from the water, soil, etc.*

   Students should understand that plants can use the cotyledon for food to begin to grow. They use food from the cotyledon whether they are in the light or in the dark. Eventually, however, the food in the cotyledon is used up. The only other way plants can get food is to make it in their leaves. To do this, they must have sunlight, air, and water. Since the plants in the dark had no sunlight, they could not make food, so they died. They could not get food from the soil. They starved to death. The plants in the light could make their own food using sunlight, air, and water.

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   Student answers typically focus on what they saw in the experiment without giving any reason. Students should be encouraged to give explanations that focus on the <u>function</u> of light for the plant (to enable plants to make their own food).

Putting It All Together - Food for Plants

We have seen that food for plants does not come from the soil or from the water or from fertilizer. Plants do not take in food from their environment.

Instead, plants have an unusual ability to take sun, water, and air and put them together in a complicated process (called photosynthesis) to make food. As long as they have light, air, and water they can make their own food. If they do not have light, they will die. They cannot make food in the dark. They can only get food by making it themselves in the sunlight.

Now let's try using these ideas to explain the experiment with the grass seed. Answer the following questions:

1. Even though grass seeds are small, they have cotyledons like the bean seeds. Tell what the cotyledons do for the young grass plants.

2. Give a reason why all of the grass plants - even the ones in the dark were able to begin growing.

3. Explain why the grass plants in the dark eventually died, while the ones in the light kept living. (Remember: A good explanation talks about what goes on inside the plants.)

This experiment asks students to keep track of a number of separate variables. This chart was designed to help students coordinate the different concepts they have learned. In class discussion, you can use this chart to help them organize these new concepts to help them make better sense of the experiment. For example, you might suggest that they look down each column in the chart in making their prediction. This would show them that only the plant without the cotyledon in the dark is totally lacking a food source.

Chapter Four - Experiment: Bean Plants With and Without Cotyledons

See if you can use what you have learned about food for plants to explain the experiment described in the next section. **Remember** that a good explanation of observations should tell what is happening inside the plants as well as what can be observed.

Bean Plant Experiment

Four bean seeds were planted in the dark. When they had each gotten about 2 inches high and had sprouted their first tiny leaves, the cotyledons were ripped off two of the plants. One of these plants without a cotyledon was put in the dark, and one was put in the light. The plants with cotyledons were also placed in light and dark conditions:

1 and 2. The purpose of this experiment and these questions is to get students to <u>apply</u> what they have learned about food for plants to make <u>accurate</u> predictions and appropriate explanations about plants grown under different circumstances.

There are three main concepts that students will need to use to give appropriate predictions and explanations:

> 1. The cotyledon is the source of food for the young germinating plant. 2. If plants have light, air, and water, they can make their own food. 3. Neither water, soil, fertilizer, sunlight, nor air is food for plants. The food for plants is <u>only</u> what the plant makes during photosynthesis.

Students have enough information now to predict that the plant in the dark with no cotyledon will die first. They should explain that the plant in the dark with no cotyledon will die because it must have food to provide the energy it needs to live and grow. It can only get food from the cotyledon or by making it itself. Since the cotyledon is gone and there is no sunlight, which is necessary for making food, the plant will die of lack of food. All the other plants in the experiment had some source of food, so they will live for at least a while.

Some students may make the correct prediction, but their reasons may focus only on observable evidence rather than on what they have learned about how plants get their food. For example, students may say the plant in the dark without the cotyledon will die first because plants can't live very long in the dark or because taking the cotyledon off the plant hurts it (like cutting off a person's head). Students should be encouraged to give <u>reasons</u> for their predictions that relate to what they have learned about <u>plants' food</u>.

3. The main concept to be applied is that fertilizer is not food. It does not provide plants with energy. The plants must have food in order to live. They will die without sunlight to make their own food, because they have no other source of food. Fertilizer is something that plants need to be healthy, but it is not food.

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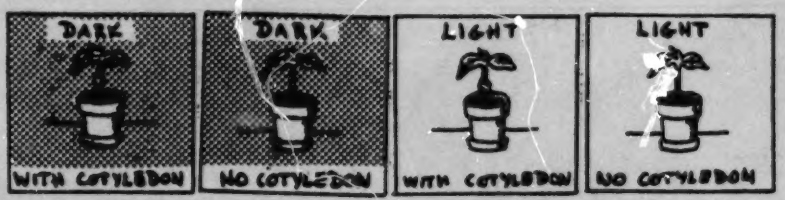
Think about the possible sources of food for each plant and fill in the following chart:



Can it make its own food?	(No)[3]	(No)	(Yes)	(Yes)
Can it get food from the cotyledon?	(Yes)	(No)	(Yes)	(No)
Can it use water as food?	(No)	(No)	(No)	(No)
Can it get food from the soil?	(No)	(No)	(No)	(No)

1. Predict which plant will die first. _____

2. Give a reason for your prediction. _____

_____

_____

_____

_____

3. Would it help the plants in the dark stay alive if you put fertilizer on them? Why or why not? _____

_____

_____

_____

_____

_____

[3]Answers in parentheses appear in teacher's manual and not in students' text.

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This application question asks students to explain the experimental results using their knowledge about how plants get food. They should integrate the key concepts of the unit:

1. *That plants cannot get any food from the soil.*

2. *That the cotyledon provides a temporary food source for new plants.*

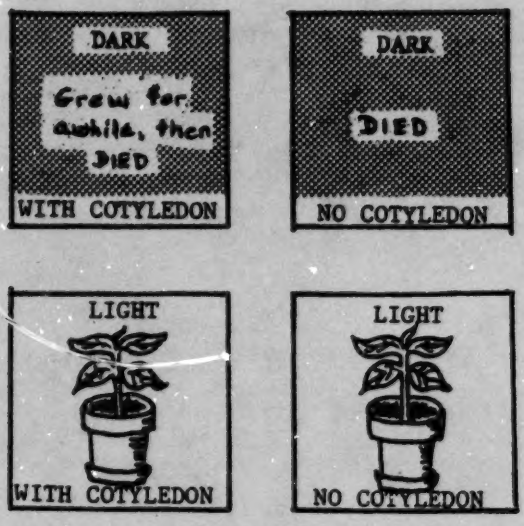
3. *That photosynthesis (plants making their own food) is the only permanent food source for plants, and light is essential for photosynthesis to take place.*

Using this knowledge, students should be able to give an explanation similar to the following:

The plant in the dark without the cotyledon had no source of food so it could not grow or live. The plant in the dark with the cotyledon grew for a while because it could get food from the cotyledon. Then it died because the cotyledon was used up, and the plant had no sunlight to use to make its own food. Plants can only get food from the cotyledon or by making it themselves.

Both of the plants in the light could use sunlight to make their own food, so they lived. Since they were in the light, it did not matter whether they had a cotyledon or not.

Now here are the results of the experiment:



Explain these results <u>using your knowledge about how plants get food</u>.

The questions on these two pages provide opportunities for students to practice using and applying all the new concepts from this unit (see page T-17). If they have given up their misconceptions about plants' sources of food and if they have understood the scientific explanations, they should be able to give answers similar to the ones below:

1. *Students need to apply two concepts: (1) that the cotyledon can be a temporary food source for young plants, even in the dark, and (2) that plants can only continue to grow if they have sun, air, and water which they can use to make their own food.*

Sample Answer

The plants will begin to grow but will eventually die. They can begin to grow using food from the cotyledon in the seed. Eventually this food will run out. Then the plant's only source of food is to make it itself using sunlight, air, and water. Since there is no sunlight in the cave, the plants cannot make their own food so they will die.

2. *The key concept to be applied is that plants do not get any food from the soil. The sprouts can get food from their cotyledons and by making it themselves. Plants do not get food from the soil, so they can survive without being grown in the soil.*

3. *The key concept is that plants must have air, water, and sun to make food, and that plants have no other source of food after the cotyledon runs out. The seeds can get food from the cotyledons, but they will not be able to make their own food when the cotyledon runs out, because air is needed for photosynthesis to take place.*

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Using Your Knowledge About Food For Plants

Now that you understand what food is for plants and where they get it, see if you can explain the following situations. Use explanations that tell what is happening inside the plant and that talk about plants' source of food.

1. Some large and some small seeds were caught in an animal's fur. The animal went into a dark, abandoned mine. Then the seeds fell out. Plants began to grow in the moist mine. Do you think the plants will survive? Why?

2. Bean sprouts are very young plants. They are used for making chow mein and other foods. Bean sprouts are easier to clean if they are not grown in soil. If the bean sprouts are not grown in soil, where would they get their food?

3. Some seeds were planted in soil, given water, and placed in a tightly sealed bottle so they could not get any air. Will the plants in the jar have a food source? Explain.

4. *The key concept here is that in photosynthesis, water, air, and light are combined to produce a <u>new</u> substance, food. They are changed into food.*

5. *The key concept is that plants make food inside their leaves. The food in the carrot was made in the leaves by the process of photosynthesis. Air and water were changed into food, which was then stored in the plants' root.*

6. *The key concept here is that photosynthesis takes place inside the plant, and we cannot see it happening. Scientists have done many experiments to learn about what is happening inside the plant, but we cannot <u>see</u> this process taking place. We can, however, use our knowledge of this process to make sense of our observations (of the grass plants, for example).*

<u>Language Arts Activity</u>

The focus in the student letters should be on providing correct explanations of how plants get food using the main concepts that plants get food only by making it themselves and that fertilizer is not food for plants. In their letters, students should explain that plants get their food by making it themselves. They may describe a little about how this process takes place. They should also point out that photosynthesis and the cotyledon are the plant's only sources of food and that plant fertilizer is not really food because it does not provide energy for the plants.

4. Some people use an equation (like 1 + 1 = 2) to describe photosynthesis. Explain what this equation means:

Water + air + light energy $\xrightarrow{\text{produce}}$ food

5. When plants make more food than they need, the extra food is stored in a part of the plant called a fruit or a vegetable. When you eat a carrot, where did that food originally come from?

Language Arts Activity

Write a letter to the makers of "Always-Grow Plant Food." Explain to them why they are guilty of false advertising. Be sure to tell them how plants really get food and why their mix of minerals is not plant food.

	How many sources of food?	What is their food?	Where do they get their food?	How do they get their food?	When can they get/make their food?
HUMANS	*Many*	*Meat, vegetables, Etc.*	*From their environment*	*Growing plants hunting, fishing, etc.*	*Anytime*
PLANTS	*One*	*What they make during photosynthesis*	*From inside themselves*	*By making it themselves*	*In daylight <u>only</u>*

Summary: How Food for Plants is Different from Food for Humans

On page 3 we said that both plants and humans need food because it gives them energy to grow and to keep all their parts functioning and living. Now that we have investigated food for plants, it is clear that in some ways food for plants is very different from food for humans. The next paragraph will describe some of the differences. After you read the paragraph, re-read it in order to fill in the chart below.

	How many sources of food?	What is their food?	Where do they get their food?	How do they get their food?	When can they get/make their food?
HUMANS					
PLANTS					

Humans have many sources of food and eat a wide variety of foods. For example, they grow plants, raise cattle, catch fish, and hunt deer. They get their food from their environment, and they can get it at any time of the day or night.

Plants, on the other hand, have only one source of food. They get their food by making it inside their bodies, not from their outside environment. This process of making food inside the plant requires sunlight, so plants can only make food in the sunlight. Even the food in the cotyledon is made by plants (the parent plants).

There are three main concepts that should be reflected in students' answers:

1. *Students should now be able to state that raw materials (air, water, sun, fertilizer) taken in by plants are <u>not</u> food for the plants.*

2. *Students should understand that the cotyledon contains food that can be used by the young plant to grow in the dark.*

3. *Students should explain that plants get food <u>only</u> by making it themselves by combining air and water in the presence of sunlight. This process is called photosynthesis. Even the food in the cotyledon was made by the parent plants during the process of photosynthesis.*

It is important that students see the incompatibility between their misconceptions and the scientific conception of food for plants.

SUMMARY: Correcting Your Definition of Food for Plants

Look back at what you said about food for plants at the beginning of this chapter (p. 4).

1. How would you change your statements to make them more accurate?

2. What did you leave out of your answer that you can now add to tell the whole story about food for plants?

Overview of Students' Misconceptions About Food for Plants

The following two charts give an overview of fifth-grade students' common misconceptions about plants and their needs for light and food. These misconceptions are contrasted with the goal conceptions of the unit. As indicated on the chart, students' misconceptions fall into two categories: Students have misconceptions at a factual level (plants get food from the soil) as well as misconceptions about how to think about their observations of plants. In thinking about plants' need for light, for example, they think only about the <u>effects</u> of light on plants (it helps them live) rather than on <u>why</u> or <u>how</u> light helps plants live.

Factual Level Misconceptions Compared To Goal Conceptions

	Misconceptions	Goal Conceptions
Why plants need light	Light is a condition or a substance needed for plants to grow or to be green.	Light is plants' energy source in making food.
Plants can live and grow	Only in the light.	In the dark, as long as they have food from the cotyledon. And in the light (can make their own food).
Food for plants is	fertilizer/plant food things plants need (raw materials such as water, sun, fertilizer, shelter) things plants take in or "eat" (raw materials such as water, fertilizer, sun)	What is made by the plant during photosynthesis. This food is stored in the cotyledon. The cotyledon provides food for the seed before it can make its own food.
Plants get food from/by	soil, water	Making it inside themselves.

Ways of Thinking About Plants and Food

	Misconceptions	Goal Conceptions
Ways of thinking about plants' need for light	Focus on observable effects--plants need light to live or to grow	Functional explanation of observable effects--plants need light to make their own food, which they need to live and grow.
Ways of thinking about where plants get food	Focus on human analogy--Plants get food from many sources	Focus on unique process in plants--Plants get food <u>only</u> by making it themselves
Ways of defining food	Focus on human analogy and observable effects--Anything that is taken into the body or that helps an organism live could be considered food.	Focus on functional scientific definition of food: plants and animals need food to supply energy for internal life processes.

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